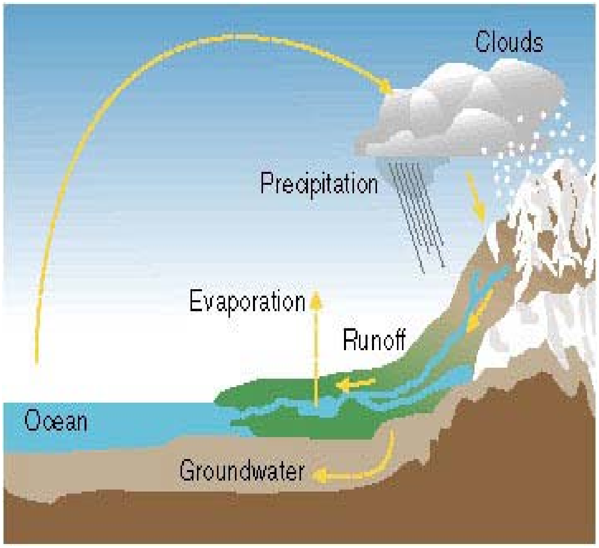
ENERGY PRODUCING SYSTEMS

HYDRO POWER

INTRODUCTION

Humans have used the power of flowing water for thousands of years. Early civilizations used wooden paddle wheels to grind corn and wheat to flour. The word *Hydro* comes from the Greek word for water. *Hydropower* traditionally represents the energy generated by damming a river and using turbine systems to generate electrical power. However, there are several other ways we can generate energy using the power of water. Ocean waves, tidal currents and ocean water temperature differences can all be harnessed to generate energy. More than 70 percent of the earth is covered in water. In many ways the earth is a water planet and the water is in constant motion thanks to the hydrologic cycle (see diagram).

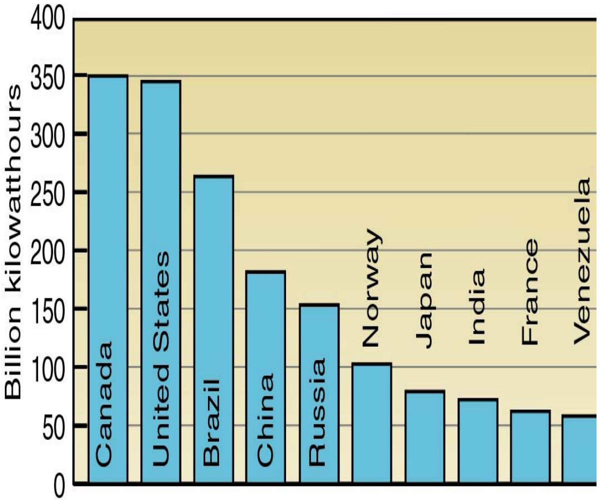
The United States is one of the worlds top producers of hydropower (see chart). As much as 12 percent of the electrical energy generated in the U.S. is currently derived from hydropower systems. Parts of the Pacific Northwest generate as much as 70 percent of their electricity using hydroelectric sources. More than half the *renewable* energy generated in the United States comes from hydroelectric dams. Hydroelectric power is currently the least expensive source of electrical power and is much cleaner than power generated using fossil fuels.



Source: Department of Energy

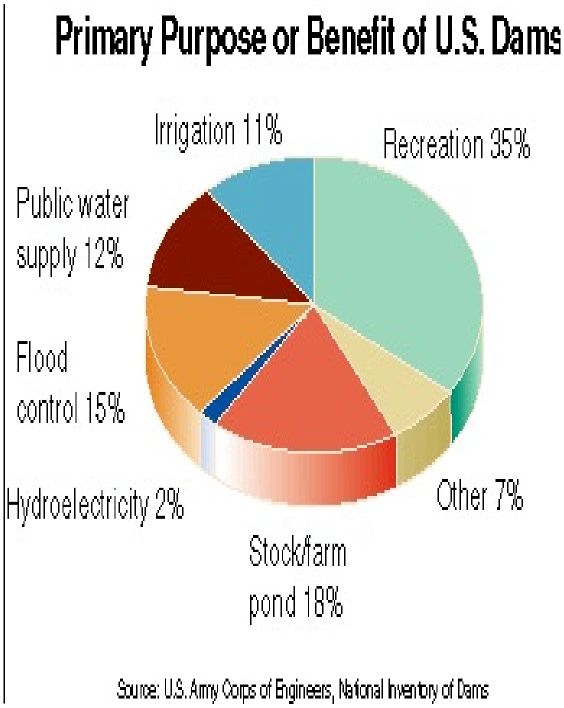
The energy to drive the hydrologic cycle is gained from the sun. Thus, hydropower is a renewable energy source and one that is prevalent all over the earth.

HYDRO POWER PRODUCTION



Source: EIA, Annual Energy Review 1997, July 1998, Table 11.15

Worldwide 20 percent of all electricity is generated using hydropower. Norway produces 99 percent of its electrical needs using hydropower and New Zealand provides 75 percent of its electrical needs with hydropower. Most of the rivers in the United States already have one or more dams constructed along their course. However, most of these dams are not used to generate energy. Only two percent of the more than 75 thousand dams in the U.S. are currently used to generate electrical power. Most dams are designed to create recreational opportunities (lakes), provide water for farm irrigation, serve as a source of public drinking water, or are used as a form of flood control (See chart).



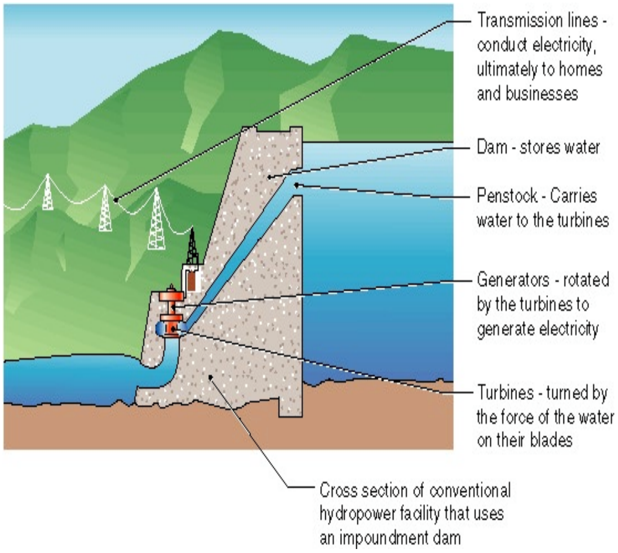
TYPES OF HYDROPOWER SYSTEMS

- IMPOUNDMENT

This type of hydropower system takes advantage of the conversion of potential energy of a dammed river to kinetic energy. The water is released from the dam through a series of pipes and used to operate turbine systems and generate electrical power. The lake volume can be regulated and represents a source of stored energy. These systems can be very efficient with as much as 90 percent of the energy being converted to electrical power.

In some cases impoundment systems are used specifically to store energy. One of the first installations of this type of *pumped storage* system was carried out by Ameren UE on a tributary of the Black River near Pilots Knob in Missouri. Electrical power generated from other sources is used to pump water up hill and fill a large storage impoundment. Typically this occurs at night when electrical consumption is low. The stored water is then “tapped” during peak energy demands to provide additional power, such as on very hot summer days when air-conditioning needs are great.

Pump storage systems offer a solution to the intermittent nature of some energy sources such as solar or wind power. During sunny or windy days electrical power can be used to pump water uphill to an impoundment for storage. During cloudy days or during periods of low wind the impoundment then serves as a back-up energy source. Such approaches allow renewable energy sources such as solar or wind power to provide consistent and uninterrupted electrical power, regardless of changes in solar availability or wind velocity.



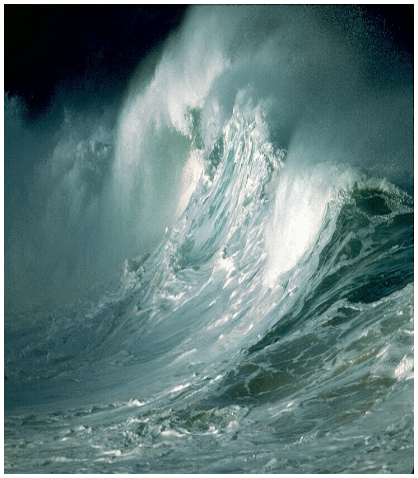
Source: INEL/DOE

- DIVERSION SYSTEMS

Diversion hydropower systems essentially channel the flow of a river or a portion of the flow to a turbine system used to generate electrical power. A set of pipes or canals is used to redirect the flow and such systems usually do not require a dam. Such systems are only applicable to very fast flowing bodies of water and the amount of power produced is very dependent on the flow. These systems cannot store power in the way a dam does and are best applied for smaller scale local power applications in remote locations away from main utility power grids.

- WAVE POWER

Any one who has gone swimming in the ocean can attest to the power of even small waves. Wave power systems involve constructing artificial canyons or troughs designed to channel the power of each wave. This motion is then used to drive turbines, compress air, or lift hydraulic pumps designed to generate electrical power. These systems are often applied to generate specific local electrical power needs such as lighting a marker buoy or providing power to a remote lighthouse. However, entire systems could be built along stretches of coast line and provide for much larger power needs.



- TIDAL ENERGY

The moon exerts a strong gravitational force on our planet. This force combined with the rotational movement of our planet creates uplift in our ocean surface every 12 hours. The level of this tidal effect is greatly influenced by the depth of the water, local ocean currents, and geological constrictions that amplify the effect. Tides can be as small as a few inches on some coastal regions (west Florida coast) to as much as 30 feet or more in other locations (upper Baja peninsula). Tidal energy systems typically involve erecting a dam across the opening of a bay. As the tide comes in the flow of water is directed towards a series of turbines to generate electrical power. As the tide recedes the flow reverses and can again be captured to generate power. Some systems use the incoming tide to fill a large reservoir system then the gates close and power is generated from the controlled outflow. This type of power system has been successfully operated in France and currently provides power to 240,000 homes.

- OCEAN THERMAL ENERGY

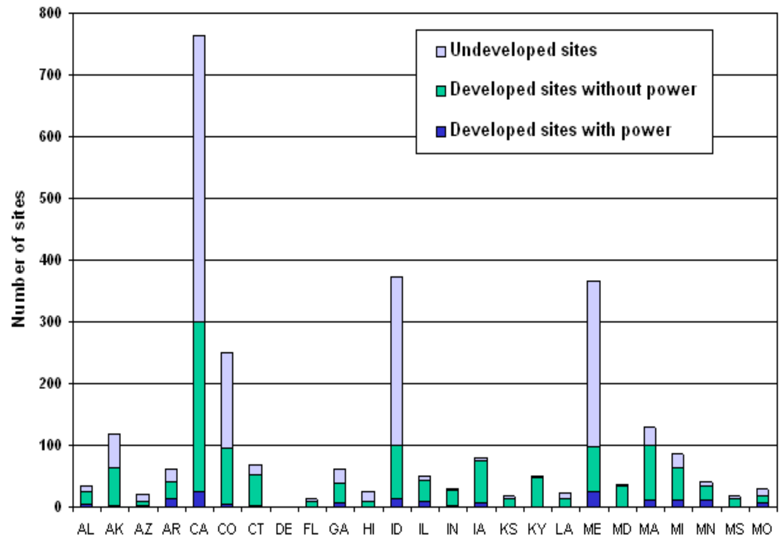
These systems take advantage of the temperature difference in ocean water with depth. The radiant energy from the sun causes surface waters to be significantly warmer than colder deep water. Such systems require at least a 40 degrees Fahrenheit difference between surface and deeper waters. The warmer surface waters are used to vaporize a working fluid with a low boiling point (such as ammonia). The expanding vapor is used to drive a turbine and generate electricity. The working fluid is re-condensed using colder deep-sea water and the process repeated. Some systems use ocean water itself as the working fluid and have the advantage of producing fresh water in the process (via distillation). Such systems can be a significant advantage in areas of the world where fresh water is limited. Ocean thermal energy systems have been successfully piloted in Japan and Hawaii. However, the power generated from these systems is still currently more expensive than electricity generated by other means (fossil fuels, hydropower, etc). In the future, as the technology for ocean thermal energy systems is refined, both energy and fresh water may be routinely obtained from the sea. Sixty percent of the world’s population is located near coastal regions and could greatly benefit from this emerging technology.

SPECIFIC CHARACTERISTICS OF HYDROPOWER

Forty years ago as much as 40 percent of the electricity generated in the United States came from hydroelectric dams. Coal-fired power utilities currently provide the majority of our electrical power and only 12 percent of electricity consumed is currently generated using hydropower. Hydropower systems represent a renewable energy source driven by the hydrologic cycle.

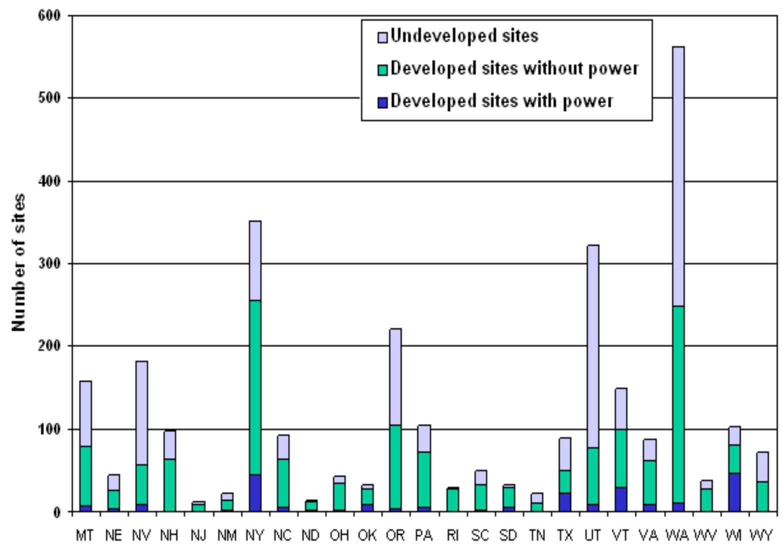
However, rivers and coastal areas are critical habitat for a substantial amount of the life found on earth. Dams certainly change the characteristics of rivers and can have drastically negative impacts on fish populations and other aquatic organisms. A dam on a river can mitigate the natural flood cycles required by some fish for breeding, can limit migrations and can significantly alter the temperature of the water. Many dam installations have been shown to increase the processes of anaerobic degradation of organic matter resulting in increased levels of atmospheric carbon dioxide. Dams also compete with other water needs such as crop irrigation, drinking water and aquatic habitat

HYDROPOWER POTENTIAL
Alaska through Missouri



Source: INEL/DOE

HYDROPOWER POTENTIAL
Montana through Wyoming



Source: INEL/DOE

protection. Water itself is becoming a precious resource as evidenced by the many lawsuits filed over water rights between the western states. In many parts of the world entire countries are in dispute over water rights. The Colorado River, for example is so heavily utilized along its course that it no longer consistently flows from the United States through Mexico to the sea. The last one hundred miles of riverbed is often dry as a result of water diversion associated with agricultural irrigation and drinking water needs.

However, many river systems in the United States already have one or more dams installed along their path to the sea and only three percent of such dams are currently used to generate electrical power. Such dams could be retrofitted with turbine systems and electrical power obtained through modification of pre-existing facilities. Hydropower has the potential to be critical facet in the application of other renewable energy systems. Wind power and solar power systems are intermittent sources of energy. Pumped storage systems can be used to generate conventional hydropower during time frames when the primary source of power (wind or solar) is unavailable. New developments in tidal, wave and thermal ocean energy also promise to aid in establishing clean and renewable energy sources. As these technologies mature their practical application will increase helping to provide power for coastal populations.

THE FUTURE OF HYDROPOWER IN MISSOURI

Missouri currently has nine pumped storage facilities, and twenty conventional hydroelectric plants. The Bagnell Dam on the Osage River (pictured above) produces 176 megawatts of power and helps avoid the emission of 220 tons per hour of carbon dioxide that would result from an equivalent coal-fired power plant. A total of 29 additional hydroelectric sites have been identified for Missouri (1993 U.S. Department of Energy study). Several of these sites are located on Ozark rivers where development would be inappropriate for environmental and cultural reasons. Even though Missouri's potential concerning hydroelectric power is less than many other states, hydroelectric power will be an important part of a more diversified, localized power distribution system. Recent developments in microturbine technologies set the stage for the development of smaller localized applications of hydropower.